

# **INSTRUMENT DESIGN AND IN ORBIT PERFORMANCE OF PLANETARY LIDARS DEVELOPED AT NASA GSFC**

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## **1. INTRODUCTION**

Space lidars provides a unique and powerful tool in earth environment monitoring and planetary exploration. Lidars operate at a much shorter wavelength than radars and can have a much narrower beam and much smaller transmitter and receiver. Lidars carry their own light sources and can continue measurement day and night, and over polar regions, where the passive instruments cannot observe. NASA Goddard Space Flight Center (GSFC) has developed several space lidars, three of them on planetary missions. These were the Mars Orbiter Laser Altimeter (MOLA) on the Mars Observer and Mars Global Surveyor missions, the Mercury Laser Altimeter (MLA) on the MErcury Surface Space ENvironment, GEochemistry and Ranging (MESSENGER) mission and the Lunar Orbital Laser Altimeter (LOLA) on the Lunar Reconnaissance (LRO) mission. These lidars all use similar technologies but with major improvement from one instrument to the next in size, power, measurement capability and operating environment.

## **2. INTSTRUMENT DESIGNS OF PLANETARY LIDARS DEVELOPED AT NASA GSFC**

All planetary lidars developed at NASA GSFC to date used diode pumped Q-switched lasers at 1064 nm wavelength with 5-8 ns pulse width. The receiver optics consisted of one or several telescopes bore-sighted with the laser beam and had a field of view larger than the laser footprint to maximize the signal and to provide adequate alignment margin. The detectors consisted of silicon avalanche photodiodes (APD), post amplifiers, matched filters, comparators, and timers to record the threshold crossing times at leading and trailing edges of the detected pulses. MOLA and LOLA could measure received pulse energy to give the surface reflectance at the laser wavelength. MLA could not directly measure the received pulse energy but could estimate it from the pulse width measurements at two different threshold levels. All the three lidar receivers monitored the noise threshold crossing rate in real time and adjust the detection threshold to achieve the highest receiver sensitivity under a given false detection rate. All of them had range gates and ground tracking algorithms to minimize the search window for the ground returns and reduce the false detection rate. The noise threshold crossing monitor data could also be used to infer the solar background seen by the receiver telescope to give a measure of the surface reflectance to the sun light at the laser wavelength.

MOLA was first developed in 1989-1991. It was designed to map the Mars surface topography from a 400 km circular orbit around Mars with about 50 mJ pulse energy at 10 Hz and a receiver telescope diameter of 0.5 meter. MOLA was first flown

on the Mars Observer mission in 1992 but did not reach the desired orbits around Mars due to a spacecraft malfunction. A second MOLA was built in 1994 to 1996 and launched in 1997 on board Mars Global Surveyor (MGS). It successfully made the surface of Mars and cloud heights with 650 million laser shots, covering the entire globe over one full Martian year (two Earth years) at about 0.25 meter precision. MOLA also measured the Mars surface reflectance to the laser light and solar background light and provided a unique map of Mars at  $1064 \pm 1$  nm wavelength.

MLA was developed from 2001 to 2003 and was designed to be a miniaturized MOLA but for a much harsher thermal environment. It used 20 mJ/pulse laser at 8 Hz and a receiver aperture equivalent to a 0.25 m in diameter telescope, mostly limited by the mass, volume and power available to the instrument. The harsh thermal environment from the sun and planet prohibited the use of lightweight Cassegrain receiver telescopes. Four smaller refractive telescopes had to be used to give an equivalent aperture of the required size. The signals from each telescope were transmitted and combine onto a single detector via optical fibers. MLA has to make range measurement from a highly elliptical spacecraft orbit around Mercury and a non-nadir laser beam-pointing angle because the sunshade of the spacecraft has to face the sun at all time. As a result, MLA has to ranges at a shallow angle and over great distances. MESSENGER was launched on August 3, 2004, and entered into orbit about Mercury on March 18, 2011. MLA started to collect science measurements on March 29, 2011. As of Dec 31, 2011, MLA had accumulated about 5 million laser ranging measurements to the Mercury surface with a maximum distance of >1500 km at near-zero laser-beam incidence angle (and emission angle) and 650 km at  $65^\circ$  incidence angle.

LOLA was developed during 2005-2008 and was designed to range to the lunar surface from a 50 km altitude. LOLA used a single stage laser at 3 mJ pulse energy and 28 Hz pulse rate to taking advantages of the relatively low spacecraft altitude. Furthermore LOLA used a diffractive optical element (DOE) on top of the laser beam expander to splits the laser beam into five beams 25 m apart on the lunar surface. There are five independent receiver channels, each looking at one laser spot on ground. As a result, it gives not only the surface elevation, but also the slope and directions from a single laser shot. LOLA also provided the surface reflectance measurements and “sees” inside the permanently shadowed craters in polar region of the moon. LOLA was launched on board LRO in June 2009 and has made about 5 billion lunar topographic measurements to date.

A detailed instrument design and performance from orbits will be presented.

### 3. REFERENCES

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